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Novel technology of frequency trimming for boundary acoustic wave RF devices using ion implantation

弾性境界波 RF デバイスの
イオン注入を用いた新しい周波数調整方法

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1. Introduction

Boundary acoustic wave(1) technology has recently received considerable attention for miniaturizing radio frequency (RF) resonators, filters and duplexers. A high accurate frequency trimming technique is necessary to realize these RF devices, because the resonant frequency (Fr) of surface acoustic wave (SAW) devices or boundary acoustic wave devices is very sensitive to the thickness, strip width and density of an inter-digital transducer (IDT) and a dielectric film covering the IDT. Generally, the Fr of the SAW devices is trimmed by etching the surface of IDT or the dielectric film on the IDT(2). On the contrary, in the case of the boundary acoustic wave devices, the same method can not be applied for frequency trimming, because the elastic wave energy concentrates on the boundary of the solids. Hence, boundary acoustic wave is awkward to use for RF devices. Authors applied an ion implantation technique to the frequency trimming process of boundary acoustic devices. The ion implantation is a technology by which ions can penetrate into another solid, thereby changing the physical properties of the solid. The depth of implantation is proportional to the ion energy. In this paper, we report experimental results of frequency shift of the boundary acoustic wave devices by using ion implantation. The frequency shift by implanting is maintained after heat-treatment, which is assumed heat-stress of reflow soldering and fabrication process.

2. Principle and Structure

Figure 1 shows the structure and the elastic energy distribution of the boundary acoustic wave device used in this experiment. This device has an upper layer SiN/SiO_2 and a lower layer $LiNbO_3$, and an IDT disposed at the interface between both two layers. The boundary acoustic wave propagates with their energy concentrated on the boundary near the IDT (shown as propagation area in Figure 1). Conducting the ion implantation, the ion is distributed to this propagation area, after passing through a part of the upper layer. It induces the change of elastic value of this part, which results in the phase velocity shift.

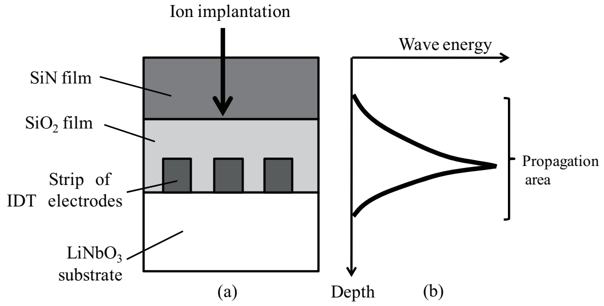

Fig.1 (a) Cross-sectional view of the boundary acoustic wave resonator (b) Distribution of the wave energy on the boundary acoustic wave.

3. Experiment and result

A one-port boundary acoustic wave resonator construction is applied to test samples. Its IDTs with the thickness of 300 nm are formed on a 25 ° Y-X $LiNbO_3$ substrate. A SiO_2 film and a SiN film are deposited on the IDTs / $LiNbO_3$ substrate, and the thicknesses of each film are 1213 nm and 400 nm, respectively. The thickness of the upper layer SiN film is 400 nm, which is thinner than that of originally required (2000 nm). The reason is that the maximum depth of peak concentration (800 - 900 nm) of Li ions is restricted by the maximum ion implantation energy of the equipment (200 keV). Under the experimental thickness of SiN, slight energy of elastic wave is known to leak to the surface.

The ion implantation into the resonators is conducted with doses varying from 10^{14} to 10^{17} ions / cm^2 at 200 keV. **Figure 2** shows dependency of the frequency shift on the Li ions implantation dose. The frequency becomes lower as the Li ions dose increase.

Figure 3 shows the impedance response of the test resonator before and after Li ion implanting with dose of 10^{16} ions / cm^2 at 200 keV. Remarkable

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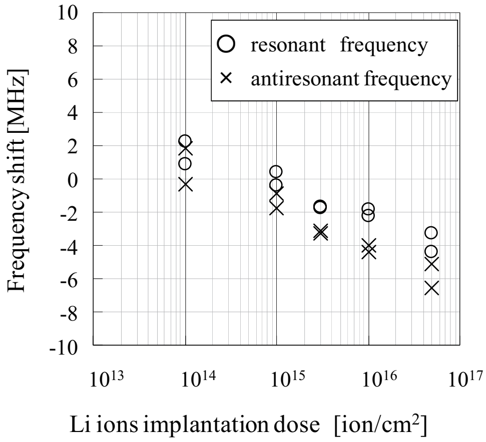

Fig.2 Dependency of the frequency shift on the Li ions implantation dose.

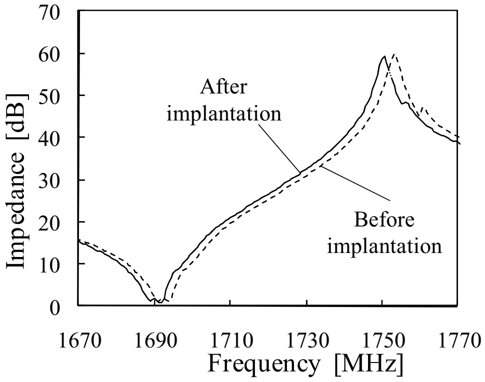

Fig.3 Impedance response of the boundary acoustic wave resonators before and after implanting with dose of 10^{16} Li ions / cm^2 at 200 keV

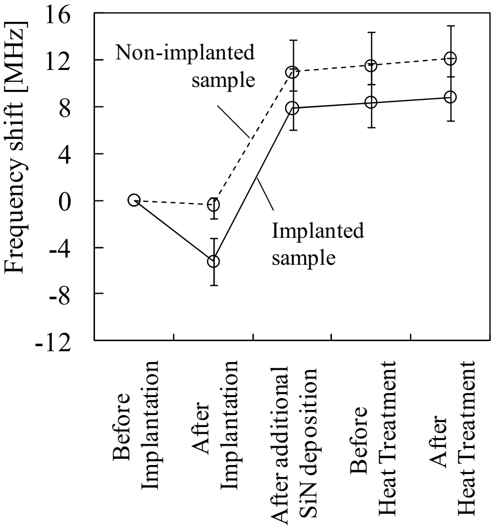

Fig.4 Fr shift in the each step of the fabrication process of implanted sample and non-implanted sample as a reference. Open circles are the average values and error bars are the max - min values of 20 samples.

degradations on the sharpness of resonance and anti-resonance cannot be observed.

After implanting, the SiN film with a thickness of 1600 nm is deposited to confine the wave energy near the IDT. And then the resonators are heated in the air at 300 °C for 1 hour, which is assumed heat stress in the reflow process to the devices. **Figure 4** shows the results of the Fr shift during the each steps of the fabrication process of implanted sample (Li, 200 keV, 10^{16} ions/cm^2). In Figure 4, Fr shift of non-implanted sample is shown for comparison. As shown in Figure 4, the Fr of implanted sample decreases about 5 MHz by ion implanting. This frequency shift value does not disappear after additional SiN deposition and after heat treatment, from comparing with the Fr shift of non-implanted sample. This result suggests that diffusion and liberation of Li ion have not occurred by deposition process and heat treatment.

4. Conclusion

The ion implantation has been conducted on the elastic wave device which leaked wave energy slightly to the surface. A remarkable frequency shift is confirmed by implanting the Li ions. The frequency shift is maintained after depositing the additional SiN and heating.

In this study, it was demonstrated that ion implantation is effective method for frequency trimming and control of the boundary acoustic device. We have the confidence that frequency can be changed even if the completely elasticity boundary wave device with thick SiN layer by means of implanting with 300 keV. This 300 keV is feasible by marketed implantation machine.

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